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THE $FeSiO_3$-$CaSiO_3$-$MgSiO_3$-$NaFeSi_2O_6$ SYSTEM OF MONOCLINIC AMPHIBOLES

A. N. WINCHELL, *University of Wisconsin*

Since the preparation of the article on the amphibole group,[1] further data have become available so that it is now possible to present a more complete account of the non-aluminous monoclinic amphiboles. The largest part of the new data was contributed by Sundius[2] in his valuable study of the gruenerite-cummingtonite-kupfferite series. Additional optic data on rare minerals composed largely of $MgSiO_3$ and $NaFeSi_2O_6$ are given in the course of this article.

The diagram of the $MgSiO_3$-$FeSiO_3$ series published by Sundius suggests[3] that magnesia-rich anthophyllite is part of the same (discontinuous) series with cummingtonite and gruenerite. This view seems improbable, since artificial $MgSiO_3$ is known in a monoclinic form, and the orthorhombic series beginning with $MgSiO_3$ is continuous, at least to types in which Fe is dominant and probably to pure $FeSiO_3$. Furthermore, the optic properties of the artificial monoclinic $MgSiO_3$ correspond well with those of the rest of the series, as shown in Fig. 1.

The data on optic axial angle in the cummingtonite series require an S-shaped curve, which will perhaps be considered improbable; since the measures are on crystals which contain from 0 (artificial $MgSiO_3$) to 30 (Mansjö cummingtonite) molecular per cent of other molecules it is not certain that the double curve is correct, but the measures make a smooth curve much more nearly than the data on extinction angle. Of course, a double curve is not impossible as shown by the condition found in the plagioclase series.

The $MgSiO_3$-$FeSiO_3$ series lies along the longest horizontal line of Fig. 2; the gruenerite-riebeckite series[4] lies along the right hand side above the $MgSiO_3$-$FeSiO_3$ series; the tremolite-actinolite[5] series lies along a short line about half way below the ferromagnesian series. Pure $CaMgSi_2O_6$, like pure $MgSiO_3$ (as monoclinic amphibole) is unknown in nature, but was probably formed artificially by Bowen.[6] Monoclinic amphiboles approaching $CaFeSi_2O_6$ in composition are unknown and probably unstable; the same is true of monoclinic amphiboles approaching $CaSiO_3$ and $NaFeSi_2O_6$ in composition; $CaFeSi_2O_6$ is included in the figure merely for convenience.

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[1] *Am. Jour. Sci.*, **CCVII**, 1924, p. 287.

[2] *Geol. För. Förh. Stockholm*, **XLVI**, 1924, p. 154.

[3] In a personal communication Dr. Sundius points out that his diagram (p. 164) shows that the index of refraction lines have a steeper slope for the orthorhombic than for the monoclinic series and states that he is "convinced that the optical properties of the two series are quite unlike."

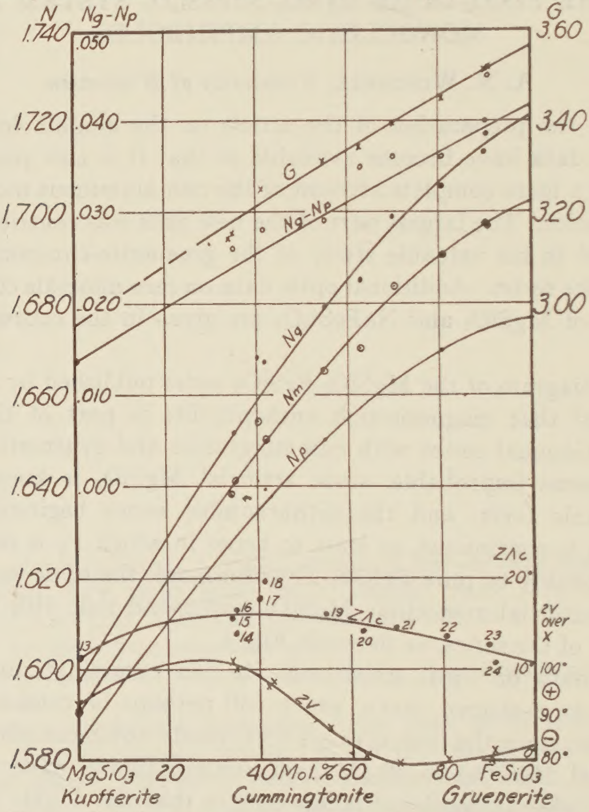

Fig. 1. Relations between optic properties and composition in the $MgSiO_3$—$FeSiO_3$ series of monoclinic amphiboles.

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[4] This series was shown in terms of weight per cent in Fig. 4 of the amphibole article. (*Am. Jour. Sci.*, CCVII, 1924, p. 307.)

[5] See *Am. Jour. Sci.*, CCVII, 1924, p. 301.

[6] *Am. Jour. Sci.*, CLXXXVIII, 1914, p. 207.

The optic properties change very rapidly in the upper part of Fig. 2, as illustrated previously in the case of the gruenerite-riebeckite series. It is worthy of note that the unusual optic orientation, which seems to the writer to be common to all compositions in the upper part of the figure, has in many cases required special and repeated study for its determination. This orientation in monoclinic amphiboles seems to be caused by $NaFeSi_2O_6$; it is found in all such minerals containing an important tenor of this molecule, and in no others. The same molecule causes very marked absorption and pleochroism in blue, green and yellow, and also very strong dispersion, resulting in incomplete extinction in white light and abnormal interference colors. Such minerals are probably stable only under a very limited range of conditions; they are rare and confined (except for riebeckite) to contact zones. In them small changes of composition cause such large changes in optic properties that the data seem somewhat discordant. This condition is believed to be due to the fact that in a single small occurrence, only the average composition of which can be obtained, the optic properties vary very considerably; and these variations

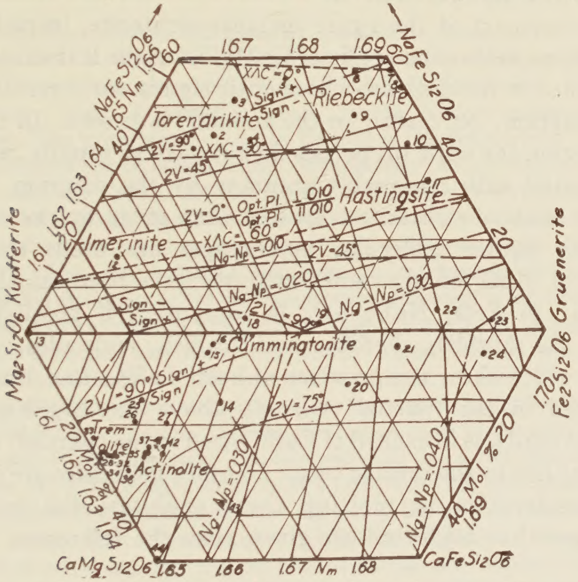

Fig. 2. Relations between optic properties and composition in the $FeSiO_3$-$CaSiO_3$-$MgSiO_3$-$NaFeSi_2O_6$ system of monoclinic amphiboles

are doubtless due to variations in composition. At the same time the diagram expresses the main facts correctly; the mean index of refraction is correct within ±.01 in all cases; the birefringence is correct within ±.005 in nearly all cases; the position of the optic plane is believed to be correct in all cases; but the extinction angle and optic axial angle are only approximately correct for imerinite (No. 12) and crossite (No. 4).

The lower part of the figure includes richterite, tremolite and actinolite, as well as the artificial $CaMgSi_2O_6$; the last substance is the only one in the diagram whose optic sign is not correctly given by the diagram. No reason for the anomaly is known. In this part of the system the optic properties do not vary so rapidly, and they are indicated with reasonable accuracy by the diagram, though the optic angle of richterite is smaller than given by the drawing.

In both figures molecular percentages are used; the small amounts of MnO found in some analyses have been calculated as equivalent to FeO; $NaFeSi_2O_6$ is computed, if possible, after forming the $MgSiO_3$, $FeSiO_3$, and $CaSiO_3$ molecules. Those analyses which show the presence of both $CaSiO_3$ and $NaFeSi_2O_6$ are plotted in the (partial) triangle above the $MgSiO_3$-$FeSiO_3$ line if $NaFeSi_2O_6$ is in excess[7] of $CaSiO_3$ and in the (partial) triangle below that line in the reverse case. All other molecules are omitted from consideration in plotting these analyses; the molecular percentages thus neglected are given after the references in each case.

Arfvedsonite and cossyrite are composed largely of $FeSiO_3$, $NaSiO_2OH$, and $NaFeSi_2O_6$; by adding another (partial) triangle at the right of the upper part of Fig. 2 they could be included in the diagram. However, the number of analyses is very small, and optic data are almost entirely lacking; the only measures of indices of refraction ever made on supposed arfvedsonite were actually made on barkevikite, according to Hintze.[8] Therefore, these minerals have been omitted; it may be noted that, as compared with gruenerite, arfvedsonite shows that $NaSiO_2OH$ causes a rapid change in the extinction angle, but has little effect on the optic angle; the tenor of $NaFeSi_2O_6$ is small and not sufficient to produce much effect on the optic angle in arfvedsonite.

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[7] Of course, in calculating molecular percentages, molecules of comparable size are considered, so that $NaFeSi_2O_6$ is compared with $Ca_2Si_2O_6$, etc. Also $CaSiO_3$ is probably present in these amphiboles, not as an independent variable, but as part of $CaFeSi_2O_6$ or $CaMgSi_2O_6$. Recent analyses by Walker (*Univ. Toronto Stud. Geol. Ser.*, **17**, 1924, p. 58) of "hastingsite" and by Shannon (*Am. Jour. Sci.*, **CCVIII**, 1924, p. 323) of "hudsonite" include too much CaO to belong to the system here studied, though closely related to it.

[8] Hdb. Mineral. **II.**, 1897, p. 1254.

REFERENCES AND DATA FOR FIGS. 1 AND 2; NOS. 13 TO 24 ON FIG. 1; ALL THE NUMBERS ON FIG. 2.

1. Torendrikite, Ambahy, Madagascar. A. Lacroix: *Comp. Rend.*, **CLXXXI,** 1920, p. 594. In addition to the constitutents shown in the diagram it contains also 7.7 molecular percent $CaSiO_3$, 3.1 $KAlSi_2O_6$, 2.1 $AlAlO_3$, 0.5 H_2SiO_3. $2V$ = very large, $Z \wedge c = 40° \pm$, $Y = b$, X = sea blue, Y = violet, Z = straw yellow. (The writer would exchange Y and Z in this description.)
2. Torendrikite, Ambatofinendrahana, Madagascar. A. Lacroix: *loc. cit.* Contains also 7.6 $CaSiO_3$, 4.4 $KAlSi_2O_6$, 3.1 H_2SiO_3. $2V$ = very large, $Y = b$, $Z \wedge c = 40° \pm$, strong dispersion. A sample of the analyzed material, very kindly supplied by Professor Lacroix, was tested by the writer with the following results. The index is $1.665 \pm .005$; cleavage fragments in oil show vertical elongation distinctly; on the cleavage face the elongation is negative, but after careful search a fragment with positive elongation was found. A fragment with parallel extinction, and therefore parallel to 100, is not normal to an optic axis, but is normal to a plane of symmetry of the triaxial ellipsoid. The optic angle is large and dispersion is so great as to prevent complete extinction in fragments parallel to 010. It seems that the optic plane must be normal to 010 with $Z = b$ and $Y \wedge c$ rather large. The data published by Lacroix (Mineral. Madagascar, **III,** 1923, p. 295), namely, Ng = 1.67, Np = 1.65, were found later.
3. Crocidolite, Golling, Salzburg. R. Doht and C. Hlawatsch: *Verh. geol. Reichsanst. Wien,* **1913.** Contains also 21.7 H_2SiO_3, 2.4 $AlAlO_3$. (Since quartz is reported as an impurity the per cent of H_2SiO_3 may be less.) Nm < 1.692, Ng-Np = .006, $Z = b$, $X \wedge c = 8°$-$11°$, $\rho < \nu$ strong, X = blue, Y = yellow, Z = violet.
4. Crossite, Coast Range, Calif. C. Palache: *Bull. Geol. Dept. U. Calif.*, **I,** 1894, p. 181. Contains also 19.8 $NaAlSi_2O_6$, 5.0 $CaSiO_3$. $X \wedge c = 13°$. Rosenbusch (Mikr. Phys., **I,** 1, p. 246) proved that this is really $Y \wedge c = 13°$ (to 30°) and $Z = b$. Larsen gives for crossite: (−) $2V$ = rather large, Ng = 1.663, Nm = 1.659 (1.670), Np = 1.657, Ng − Np = .006, $Y \wedge c = 10°$.
5. Crocidolite, Berks Co., Pa. E. T. Wherry and Earl Shannon: *Jour. Wash. Acad. Sci.*, **XII,** 1922, p. 242. Contains also 18.7 H_2SiO_3, 1.9 $FeFeO_3$, 1.6 $TiTiO_3$, 1.0 $AlAlO_3$. First described (*Am. Mus. Nat. Hist.*, **XXXII,** 1913, p. 517, as having (−)$2V$ = large and $Z \wedge c = 3°$ to 15°, but Wherry and Shannon give $X \wedge c = 3°$ to 15° with Ng = 1.66, Nm = 1.65, Np = 1.64-1.65, Ng-Np = variable but weak, dispersion strong.
6. Crocidolite, So. Africa. A. H. Chester and F. J. Cairns: *Am. Jour. Sci.*, **CXXXIV,** 1887, p. 116. Contains also 19.5 H_2SiO_3, 3.9 $FeFeO_3$, 1.5 $CaSiO_3$. A. Johnsen (*Cent. Mineral.*, **1910,** p. 353) gives for crocidolite from So. Africa, but not for analyzed material: (+)$2V > 56°$, $X = b$, strong dispersion; this is not in harmony with other results.

7. Osannite, Cevadaes, Portugal. C. Hlawatsch: *Festsch.*, H. Rosenbusch, **1906**, p. 74. Contains also 7.1 H_2SiO_3, 4.3 $KAlSi_2O_6$, 1.9 $CaSiO_3$. $(-)2V$ = large, Ng-Np = .003-.004, $Z=b, X\wedge c=0°$ red, 5° blue; X = blue, Y = yellow, Z = green,
8. Riebeckite, Quincy, Mass. C. Palache and C. H. Warren: *Am. Jour. Sci.*, **CLXXXI**, 1911, p. 547. Contains also 9.8 H_2SiO_3, 2.8 excess SiO_2, 3.3 $NaAlSi_2O_6$, 2.7 $CaSiO_3$, 0.9 $TiTiO_3$. $(-)$ $2V$ = large, Nm = 1.695, Ng-Np = weak. $Z=b, X\wedge c=4$ ±, X = blue to green, Y = yellow, Z = green to black.
9. Osannite, Alemtejo, Portugal. A. Osann and O. Umhauer: *Sitz. Akad. Wiss. Heidelberg*, A. **1914**, Abh. 16. Contains also 5.7 H_2SiO_3, 4.5 $CaSiO_3$, 3.8 $KSiO_2$ OH. $(-)2V$ = large, Ng-Np = weak, $Z=b$, $X\wedge c=3°\text{-}5°$, extinction on 110 = 2.5°, X = blue, Y = yellow, Z = dark green.
10. Hastingsite, Hastings Co., Ont. F. D. Adams and B. J. Harrington: *Am. Jour. Sci.*, **CLI**, 1896, p. 210. Contains also 21.7 $CaAlO_2(OH)$, 3.1 $AlAlO_3$, 2.3 $FeFeO_3$. Nm = 1.69, Ng-Np = weak, $(-)$ $2V=30°\text{-}45°$, $\rho>\nu$ strong, $Z\wedge c$ = 25°-30° in obtuse angle β. But Graham (*Am. Jour. Sci.*, **CLXXVIII**, 1909, p. 540) has shown that the optic plane is normal to 010, at least in green, with $2V$ = very small.
11. Hastingsite, Almunge, Sweden. P. Quensel: *Bull. Geol. Inst. U. Upsala*, **XII**, 1913. Contains also 16.5 $CaAlO_2(OH)$, 5.1 $CaSiO_3$, 4.9 $AlAlO_3$, 1.5 $KSiO_2(OH)$. $2V=0°$ ±, optic plane parallel and normal to 010, Z or $Y\wedge c=35°\text{-}41°$, X = yellowish green, Y = bluish green, Z = green.
12. Imerinite, Ambatoharina, Madagascar. A. Lacroix: Mineral. France, **IV**, 1910, p. 787. Contains also 16.3 $NaSiO_2(OH)$ 5.7 $(Na,K)AlOF_2$, 5.1 $CaSiO_3$. $(-)2V$ = small, $Z\wedge c$ is near 45° with strong dispersion, zonal. A sample kindly supplied by Prof. Lacroix gives N = 1.650 ± .005, Ng-Np = .020 ± .005, $X\wedge c$ = 23° ± 3° (red), 13° ± 3° (blue), but this has X = bluish green, Y = slate blue, Z = pale green, and therefore probably is not exactly of the same composition as the sample described by Lacroix, which has X = pale yellowish green, Y = violet blue, Z = pale bluish green. The data published by Lacroix (Mineral. Madagascar **III**, 1923, p.295), namely Ng = 1.653, Np = 1.638 were found later.
13. Artificial. F. E. Wright: *Am. Jour. Sci.*, **CLXXII**, 1906, p. 403, and A. N. Winchell, *Am. Jour. Sci.*, **CCVII**, 1924, p. 295. $(+)2V=88°$, Ng = 1.597, Nm = 1.590, Np = 1.582, Ng-Np = .015, $X\wedge c=79°$.
14. Cummingtonite, Mansjö Mt., Sweden. H. v. Eckerman: *Geol. För. Förh. Stockholm*, **XLIX**, 1922, p. 303. Contains also 17.3 H_2SiO_3, 9.8 $AlAlO_3$, 4.3 $NaFeSi_2O_6$, 1.3 $NaSiO_2(OH)$, 0.8 $TiTiO_3$. $(-)$ $2V$ = 79°58′, Ng = 1.6519, Nm = 1.6410, Np = 1.6259, Ng-Np = .026, $Z\wedge c=13.8°$.
15. Cummingtonite, Kongsberg, Norway. A. Des Cloizeaux: *Nouv. Rech. Mem.*, **XVIII**, 1867, Dana: Syst. Mineral. p. 390. Contains also 5.6 H_2SiO_3. Nm = 1.638. $(+)$ $2V=77°58'$, $\rho<\nu$, $Z\wedge c=15°\text{-}16°$.
16. Cummingtonite, Greenland. A. Des Cloizeaux: *loc. cit.* Contains also 12.2. H_2SiO_3. $(+)2V=77°$ ±, $Z\wedge c=16°\text{-}17°$.
17. Cummingtonite, Orijarvi, Finland. P. Eskola: *Bull. Com. Geol. Finlande.* **XL**, 1915, p. 183. (Analysis incomplete.) Nm = 1.642, Ng-Np = .026, $(+)$ $2V>80°$, $Z\wedge c=20°$.
18. Cummingtonite, Röbergsgruvan, Sweden, N. Sundius: *Geol. För. Förh, Stockholm*, **XLVI**, 1924, p. 154. Contains also 2.0 $CaSiO_3$ (incomplete analysis). $(+)2V=84°$, Ng = 1.667, Nm = 1.650, Np = 1.639, Ng-Np = .028, $X\wedge c=70.5°$.

19. Cummingtonite, O. Silvergruvan, Sweden. N. Sundius: *loc. cit.* Contains also 13.6 H_2SiO_3, 0.6 $CaSiO_3$, 0.4 $FeFeO_3$, 0.3 $AlAlO_3$. $(-)2V=87^\circ$, Ng=1.679, Nm=1.665, Np=1.650, Ng-Np=.029, $X\wedge c=74^\circ$.
20. Cummingtonite, Brunsjögruvan, Sweden, N. Sundius: *loc. cit.* Contains also 12.6 H_2SiO_3, 0.4 $AlAlO_3$, 0.2 $FeFeO_3$. $(-)2V=81^\circ$, Ng=1.685, Nm=1.670, Np=1.650, Ng-Np=.035, $X\wedge c=75^\circ$.
21. Gruenerite, Stromshult, Sweden. J. Palmgren: *Bull. Geol. Inst. U. Upsala,* **XIV,** 1917, p. 109, and N. Sundius: *loc. cit.* Contains also 13.3 H_2SiO_3, 0.6 $FeFeO_3$, 0.6 $AlAlO_3$. $(-)2V=79.2^\circ$, Ng=1.699, Nm=1.6835, Np=1.663, Ng-Np=.036 (.040), $X\wedge c=75.5^\circ$.
22. Silvbergite, Silvberg, Sweden. N. Sundius: *loc. cit.* Contains also 2.5 $CaSiO_3$, 2.2 $AlAlO_3$ (incomplete analysis). $(-)2V=80^\circ$, Ng=1.7057, Nm=1.6904, Np=1.6696, Ng-Np=.0361, $X\wedge c=75.6^\circ$.
23. Dannemorite, Dannemora, Sweden. N. Sundius: *loc. cit.* Contains also 2.3 $CaSiO_3$, 0.6 $AlAlO_3$ (incomplete analysis). $(-)2V=80^\circ$, Ng=1.713, Nm=1.697, Np=1.673, Ng-Np=.040, $X\wedge c=77.5^\circ$.
24. Gruenerite, Collobrières, France. S. Kreutz: *Sitz. Akad. Wiss. Wien,* **CXVII,** 1908, p. 875. Contains also 6.4 H_2SiO_3, 4.0 $NaFeSi_2O_6$, 1.3 $AlAlO_3$ $(-)2V=82^\circ$ ±, Ng=1.717, Nm=1.697 (1.695), Np=1.672, $X\wedge c=79^\circ$-80°.
25. Richterite, Langban, Sweden. Lévy and Lacroix: Minér. Roches, **1888,** p. 144. Analysis by Michaelson. Contains also 14.9 $KSiO_2(OH)$, 4.8 $NaFeSi_2O_6$, 1.1 $NaAlO(OH)_2$. (−) Ng=1.64, Nm=1.63, Np=1.62, Ng-Np=.024, $X\wedge c=70^\circ$ (73°).
26. Richterite, Sweden. S. Kreutz: *loc. cit.* Contains also 11.1 $(Na,K)SiO_2(OH)$, 5.6 $NaFeSiO_6$, 2.4 H_2SiO_3. $(-)2V=70^\circ 33^1$, Ng=1.6367, Nm=1.6294, Np=1.6151, Ng−Np=.0215, $X\wedge c=73^\circ 5^1$.
27. Richterite, Langban, Sweden. See No. 25. Analysis by Engstrom. See Dana: Syst. Mineral. Contains also 13.7 $NaSiO_2(OH)$, 4.9 $NaAlO(OH)_2$.

28-32. Tremolite, See *Am. Jour. Sci.,* **CCVII,** 1924, p. 306.

33. Tremolite, Edwards, N. Y., E. T. Allen and J. K. Clement: *Am. Jour. Sci.,* **CLXVI,** 1908, p. 101. Contains also 4.9 H_2SiO_3, 4.9 $(K,Na)SiO_2OH$, 3.7 $Na(Al,Fe)Si_2O_6$. No optic measures.
34. Nephrite, Bahia, Brazil. H. S. Washington: *Pan-Amer. Geol.,* **XXXVII,** 1922, p. 198. Contains also 12.2 H_2SiO_3, 2.8 $NaAlSi_2O_6$, 0.2 $AlAlO_3$, 0.2 $FeFeO_3$. Ng=1.625, Np=1.597, $X\wedge c=74^\circ$.
35. "Hornblende," Russel, N. Y., S. Kreutz: *loc. cit.* Contains also 9.8 $NaSiO_2$ (OH), 2.4 $AlAlO_3$, 2.1 $NaFeSi_2O_6$, 1.2 H_2SiO_3. $(-)2V=86^\circ 14'$, $\rho>\nu$ weak. Ng=1.6244, Nm=1.6134, Np=1.6017, Ng-Np=.0227, $X\wedge c=70^\circ 29'$.
36. Tremolite, Nordmark, Sweden: G. Flink: *Zeit. Kryst.,* **XV,** p. 90. (Analysis incomplete.) $(-)2V=84^\circ 9'$, Nm=1.618, $X\wedge c=72^\circ 42'$.

37-41. Actinolite, see *Am. Jour. Sci.,* **CCVII,** 1924, p. 306.

42. Actinolite, Berkeley, Calif., W. C. Blasdale: *Bull. Geol. Dept. Univ. Calif.,* **II,** p. 328. Contains also 14.8 $NaAlSi_2O_6$, 4.1 H_2SiO_3. Ng=1.6529, Np=1.6267, $X\wedge c=75^\circ 26'$.
43. Actinolite, Dubostica, Bosnia. M. Kispatic: *Zeit. Kryst.,* **XXXVI,** 1902, p. 649. Contains also 12.4 $CaAlO_2(OH)$, 0.8 $AlAlO_3$. No optic measures.
44. Artificial monoclinic amphibole not certainly of composition indicated, but made from 85% $CaMgSi_2O_6$ and 15% SiO_2. N. L. Bowen: *Am. Jour. Sci.,* **CLXXXVIII,** 1914, p. 207, and **CCVII,** 1924, p. 296. $(+)\ 2V=45^\circ$, Ng=1.638, Nm=(1.623) Np=1.620, $X\wedge c=23^\circ$.

PSEUDO-ISOMORPHISM AS ILLUSTRATED IN THOMSONITE

EDGAR T. WHERRY, *Washington, D. C.*

INTRODUCTION

Thomsonite may seem hardly of sufficient importance to justify such extended discussions of its composition as have recently appeared;[1] yet, as it illustrates so well certain principles of mineralogical research, this further contribution to the subject will, it is hoped, not be considered superfluous.

That the analysis of a mechanical mixture will give the same results as that of an isomorphous mixture of the same components in corresponding proportions is such a self-evident proposition that its general recognition and acceptance would surely be expected; yet every now and then articles appear in which it is overlooked. Before the development of modern microscopic methods of study of minerals this was more or less excusable; but at the present day it is surely not going too far to hold that *no claim of the isomorphism of two or more compounds should be accepted unless accompanied by optical evidence.*

THE COMPOSITION OF THOMSONITE PROPER.

In the paper noted, Gordon expressed surprise that the writer should consider a mineral to have a definite formula when by laboratory experiments its lime can be replaced by soda, potash, etc. As a matter of fact, numerous minerals of quite definite formulas can be so changed, and this has no bearing on the matter at all. He then (unconsciously) obscured the very replaceability he was trying to prove by recalculating a series of analyses of miscellaneous minerals, loosely classified as thomsonite, on the basis of $Na_2O = 1$. To really demonstrate mutual replaceability it would have been necessary at least to use the *sum* of the Na_2O and CaO as unity (or a small integer); but even this is not the most informing procedure.

The method brought to the attention of mineralogists by Schaller[2] some years ago has not been used as widely as seems desirable. As pointed out by several writers who discussed the subject at the time, least square methods of reduction would be more acceptable from the mathematical viewpoint, but most analytical data are not of sufficient accuracy to justify this, so the original plan is here favored. In brief, this is to divide each ratio by the nearest integer obtained by inspection, find the average of the several quotients, and divide each ratio in turn by this average.

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[1] The writer, *Am. Min.*, **8**, 121-125 (1923); S. G. Gordon, *Proc. Acad. Nat. Sci. Philadelphia*, **76**, 103-107 (1924); A. N. Winchell, *Am. Min.*, **10**, 90-97 (1925).

[2] *U. S. Geol. Survey Bull.*, **610**, 163-164 (1915).

By thomsonite is here understood the mineral to which the name was originally given. To arrive at its formula, the Schaller method will be employed, but only the three analyses made on material of known optical character will be admitted. The transparent columnar mineral from Scotland, the type of the species, has been found by the writer to be optically homogeneous; the most modern analysis of it, that by Tschermak,[3] may be used. The data are as follows (in all the analyses any K_2O is added to Na_2O, and Fe_2O_3 to Al_2O_3):

	Analysis	Ratio	Int.	*r/i*	*r/av.*
Na_2O	4.01	0.065	1	0.0650	1.04×1
CaO	13.55	0.242	4	0.0605	0.97×4
Al_2O_3	31.63	0.310	5	0.0602	0.97×5
SiO_2	37.73	0.628	10	0.0628	1.01×10
H_2O	13.52	0.750	12	0.0625	1.01×12
Sum	100.44			av. 0.0622	

The mineral described by Gordon from Franklin Furnace, New Jersey, had optical properties identical with those of the preceding material, and so is undoubtedly also thomsonite. Its $CaO : Na_2O$ ratio and $Al_2O_3 : CaO + Na_2O$ ratio are both somewhat abnormal, (yielding a long line in Winchell's diagram) perhaps owing to the presence of a small amount of calcium carbonate in the sample analyzed; but the deviation from the formula of the type thomsonite is not great, as the tabulation shows:

	Analysis	Ratio	Int.	*r/i*	*r/av.*
Na_2O	3.68	0.059	1	0.0590	0.94×1
CaO	15.94	0.284	4	0.0710	1.13×4
Al_2O_3	30.34	0.297	5	0.0594	0.95×5
SiO_2	36.44	0.606	10	0.0606	0.97×10
H_2O	13.52	0.750	12	0.0625	1.00×12
Sum	99.92			av. 0.0625	

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[3] *Sitzb. Akad. Wien,* **126,** 545 (1917).

The thomsonite from Peekskill, N. Y., described by Phillips[4] shows indices agreeing with those of the two preceding minerals within the limits of accuracy of the immersion method, and its analysis gives:

	Analysis	Ratio	Int.	r/i	r/av.
Na_2O	4.02	0.065	1	0.0650	1.04×1
CaO	13.80	0.246	4	0.0615	0.99×4
Al_2O_3	31.65	0.310	5	0.0620	0.99×5
SiO_2	37.44	0.623	10	0.0623	1.00×10
H_2O	13.22	0.734	12	0.0612	0.98×12
Sum	100.13			av. 0.0624	

It is concluded from these data that the formula of the mineral to which the name thomsonite was originally assigned, and of material from other localities agreeing with it in optical properties —$\alpha = 1.525$, $\beta = 1.530$, $\gamma = 1.540$, all ± 0.005—is $Na_2O.4CaO.5Al_2O_3.10SiO_2.12H_2O$. This is the formula previously obtained by the writer by a somewhat different procedure. Winchell adopted twice this formula, in order to show apparent isomorphism, and then added one extra H_2O, on the basis of Gordon's plotting of the H_2O contents of thomsonite and related minerals. That plot is misleading, however, in that all the ratios given are referred to $Na_2O = 1$, which exaggerates deviations in the constituents with the higher ratios, and, moreover, the line is not drawn accurately through the center of the points plotted, so the indication as to water content of the analyses above worked out appears to the present writer more dependable. This is, namely, 12 H_2O to the single molecule, or 24 H_2O to the doubled one.

THE ALLEGED THOMSONITE SERIES

Many analyses are on record, of material which the analysts called thomsonite, in which both the silica and soda are higher than in thomsonite as above defined. This has been interpreted by several students as due to isomorphism of the valence-for-valence replacement type, and their conclusions are accordingly without significance; but Winchell has endeavored to account for it on the basis of volume-for-volume replacement, so that his results are worth further consideration. As the one who first urged upon mineralogists the fundamental significance of the volume-for-volume type of isomorphism, the present writer should be glad to welcome any new illustrations of this relationship, and desires to state that in his opinion, if any isomorphism occurs in the thomsonite series, then Winchell's explanation of it may well be the correct one. He is, however, still awaiting optical evidence of the existence of such a series. The situation is not analogous to that of the plagioclases to which Winchell refers, for in it there is optical evidence of isomorphism.

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[4] *Am. Min.*, 9, 240-241 (1924).

The lowest refractive index of normal thomsonite never having been observed to go much below 1.520, whereas the highest indices of most other zeolites are decidedly less than this, a simple way to study the matter suggests itself, namely, to examine fragments immersed in a liquid with $n = 1.518$. This the writer has done in the case of over twenty-five specimens labelled thomsonite in mineral collections, widely separated localities being represented. In every case except those above cited, more or less admixture with zeolites having all their indices below that of the liquid has been observed. In some instances, such as the mineral from Magnet Cove, from Kaaden, Bohemia, and from Monte Somma, Italy, the amount of the low-index zeolite was so small that their analyses might have been safely used in arriving at the formula of thomsonite proper. In other cases, as that from Minnesota, about half the grains had the high indices of thomsonite, and the remainder were a mineral of lower indices. In still others such as the well-known Table Mountain, Colorado, specimens, and the fibrous masses from Nova Scotia and from the Faroes, the bulk of the material had all three indices lower than the liquid. In some cases the low-index mineral could be definitely identified as mesolite or natrolite; in others it was a seemingly unrecognized species, the prior name for which, as pointed out in the writer's earlier paper, is faroelite. The important point is that material labelled thomsonite in collections (and analyzed under that name) is not uniform, but represents either thomsonite proper, faroelite, (a somewhat similar zeolite with all three indices lower than the lowest of thomsonite), or mechanical mixtures of these with one another or with other zeolites not related to thomsonite at all. There is no optical evidence whatever that any isomorphous series is represented.

THE COMPOSITION OF FAROELITE

Unfortunately, only a single analysis of this mineral on material of entirely satisfactory optical character is available, namely, that made by Hillebrand (Doelter No. 50), the locality being Table Mountain, Colorado, and the specimens being preserved in the U.S. National Museum. The data are:

	ANALYSIS	RATIO	INT.	r/i	$r/av.$
Na_2O	5.62	0.091	1	0.091	0.94×1
CaO	11.34	0.202	2	0.101	1.04×2
Al_2O_3	29.71	0.291	3	0.097	1.00×3
SiO_2	41.21	0.686	7	0.098	1.01×7
H_2O	12.20	0.677	7	0.097	1.00×7
Sum	100.08			av. 0.097	

As far as it goes, then, this analysis indicates faroelite to have the composition $Na_2O.2CaO.3Al_2O_3.7SiO_2.7H_2O$, or $Na_2Ca_2Al_6Si_7O_{26}.7H_2O$. This is a somewhat simpler formula than was previously suggested by the writer on the basis of averaging several analyses; however, as further optical study has indicated the presence of admixture in materials corresponding to the descriptions of the samples analyzed in most of these cases, this new result is probably nearer the true formula of the mineral, although of course further analyses on optically controlled material will be necessary before it can be regarded as settled. As previously stated, the refractive indices of this mineral are: $\alpha = 1.512$, $\beta = 1.513$, $\gamma = 1.518$, all ± 0.005.

RE-INTERPRETATION OF WINCHELL'S THOMSONITE DIAGRAM

As the result of his fairly extensive optical studies, made on as many samples corresponding in description to those analyzed as has been practicable, the writer sees in Winchell's diagram (*op. cit.*, p. 95) *not* a continuous series, but three different things: thomsonite, in part with minor amounts of admixture, in the cluster of analysis-points lying below line 60; faroelite, likewise with admixtures, in the other close group of points between horizontal lines 60 and 70; and, in the widely outlying points, mechanical mixtures with large quantities of other zeolites, as for instance with natrolite in No. 61 (which lies on a line connecting thomsonite with natrolite), and with mesolite in No. 52 (in which material mesolite can be readily recognized optically).

SUMMARY AND CONCLUSIONS

Now that the immersion method for the optical study of minerals is available, no claim of isomorphism between two or more compounds should be accepted unless accompanied by optical evidence. Extensive optical study of specimens labelled thomsonite in collections has failed to yield evidence of isomorphism, but instead has shown the presence of two distinct species, often more or less admixed with other zeolites. By applying the Schaller method of reducing the ratios derived from a mineral formula, and using only analyses on optically satisfactory material, it is shown that thomsonite proper, the mineral to which the name was originally assigned, has the formula $Na_2O.4CaO.5Al_2O_3.10SiO_2.12H_2O$. Some specimens labelled thomsonite consist of faroelite, which may be $Na_2O.2CaO.3Al_2O_3.7SiO_2.7H_2O$, but needs further study. Winchell's diagram, when considered in the light of the optical data, confirms the existence of these two species, and demonstrates graphically what had already been suspected from optical observations, that certain of the analyses in the literature ascribed to thomsonite have been made upon mechanical mixtures. The alleged thomsonite series represents, in the writer's opinion, only pseudo-isomorphism.

THE OCCURRENCE OF A LARGE IRON-TOURMALINE IN ALABAMA PEGMATITE

Frank R. Van Horn, *Case School of Applied Science*

Some years ago Mr. Hubert H. Ward and Mr. B. E. Broadwell, Case, class of '08, found a large iron-tourmaline crystal in a weathered pegmatite dike in eastern Alabama, and presented the same to the Department of Geology and Mineralogy at Case. This occurrence was described by the writer at the thirtieth annual meeting of the Geological Society of America at St. Louis, Missouri, on December 29, 1917, and a brief abstract was published in the Bulletin of the Society.[1] It has been suggested recently that the readers of the American Mineralogist would be interested in a description of the specimen and in seeing the photographs of the same.

In the vicinity of Micaville, Randolph County, Alabama, there are many pegmatite dikes. In Township 18, Range 10 and 11 East, there are thirteen of these dikes which are approximately parallel and strike northwest and southeast, according to the information given to the writer. They vary in width from six inches up to forty feet, and occur in what is locally called the Ashland Mica Schist. The dikes are generally found parallel to the foliation planes of the schist which becomes rich in garnets at the contact, and is said also to contain cyanite. The chief minerals of the pegmatites are quartz, orthoclase, muscovite, biotite, iron-tourmaline and beryl. The mineral content of the dikes varies from nearly pure orthoclase up to almost pure quartz, and the muscovite, for which the dikes were originally exploited, seems to be found in greater quantity when quartz is present in large amounts. The pegmatites are usually weathered to kaolinite from depths ranging from ten down to ninety feet. The quartz occurs always in very large masses, sometimes weighing several hundred pounds, but crystal faces are generally lacking. The orthoclase, on the other hand, is seldom larger than a few inches, and crystal planes are likewise rare. The muscovite occurs in well formed crystals, which range in size from microscopic ones up to those which weigh three hundred pounds. The iron-tourmalines are commonly found in all sizes up to ten inches long and six inches in diameter. Beryls were not plentiful, but crystals have been found as large as five inches long, and three inches in diameter.

[1] *Bull. Geol. Soc. Am.*, **29**, No. I, p. 104-105, March 1918.

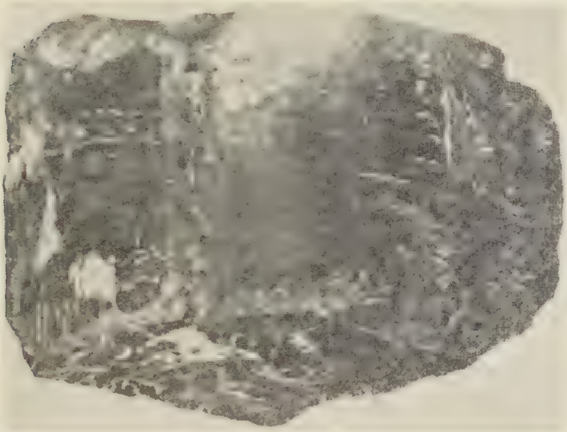

Fig. 1. Side View of Iron Tourmaline 7 inches high and 10 inches in diameter weighing 43½ pounds. Originally 3 to 3½ feet long and weighing probably 225 to 250 pounds.

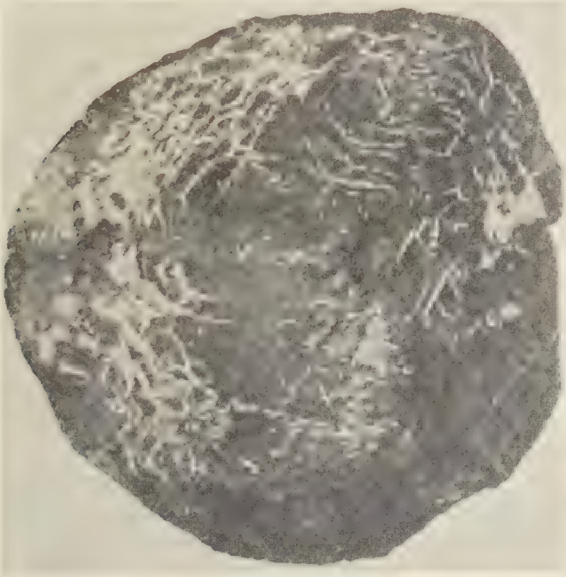

Fig. 2. Bottom view of Large Iron-Tourmaline.

The large iron-tourmaline was found by Mr. Broadwell in the shaft of Mine No. 5 of the Great Southern Mica Company about one half mile from Micaville. This shaft was in the largest dike, which was about forty feet wide, and the crystal was found at a depth of about seventy feet. The dike was weathered to a depth of eighty feet. The tourmaline was originally from three to three and one half feet long and probably weighed from 225 to 250 pounds. As far as the writer's knowledge is concerned, it is one of the largest crystals of tourmaline ever discovered. At present the specimen is seven inches high and ten inches in diameter, and weighs 43½ pounds. The faces are rough, and vertically striated due to oscillatory combination of the two prisms, but the three planes of ∞P $(10\bar{1}0)$, and the six faces of $\infty P\,2$ $(11\bar{2}0)$ are easily distinguishable. The crystal is terminated by R $(10\bar{1}1)$ which is immediately below the prism of the first order, ∞P $(10\bar{1}0)$, and is therefore the blunter end of the original hemimorphic crystal which, according to Gustav Rose, is the analogue pole in the development of pyroelectricity. Figure 1 is a side view which shows many cracks nearly perpendicular to the vertical axis, but which may be only a development of the subconchoidal to uneven fracture. Figure 2 is the bottom view of the crystal. Certain white markings are visible in three directions at approximately 120 degrees, which are roughly parallel to the edges of the rhombohedron. The white particles which render the markings more visible consist of a mixture of quartz and muscovite scales.

A VISIT TO THE LOCALITY OF NEWTONITE

Edgar T. Wherry, *Washington, D. C.*

In connection with the writer's studies on the aluminium silicate minerals, it seemed desirable to obtain specimens of as many of the rarer clays as practicable, so that analyses could be made on optically controlled material. One species of particular interest was newtonite, recorded in Dana as occurring only "on Sneed's Creek, in the northern part of Newton County, Arkansas." In the course of a recent trip through that region (taken primarily for the study of the vegetation) an opportunity to visit the locality presented itself, and directions for finding it seem worth placing on record for the aid of others who may desire to go there.

The locality is situated on the Harrison Quadrangle, Arkansas-

Missouri, of the U. S. Geological Survey. Starting out from Harrison, the main road running southwestward (in 1925 not completed, but ultimately to extend to Fort Smith) is followed. About 25 kilometers (16 miles) from Harrison the tiny settlement of Compton is passed, recognized by the right-angled turn of the road from south to west; and 6.5 km. (4 m.) further west, where the road swings southward, one's auto must be parked and the journey continued on foot.

An indistinct road, used to haul out timber, extends east from the main road down into the gorge of Sneed's Creek (which rises somewhat further west than shown on the map) and this is to be followed about 200 meters, to a point where the slope becomes very steep. Then, on scrambling down the hillside perhaps 100 meters, a group of small prospect pits will be more or less plainly seen. These have long since fallen shut, and good sized trees are growing on the dumps, but the light color of many of the fragments renders them rather conspicuous against the brown forest soil. On digging into the mass of decomposed shale—a pickaxe and spade will be found useful—occasional small lumps of a soft, white, chalky material, more or less stained by iron oxides, are encountered; and this is the newtonite. Under the microscope it is seen to be made up of minute grains of nearly square outline, which have been variously interpreted as rhombs or as tetragonal bipyramids, but which, it is hoped, can now be further studied. The small amount obtained has been deposited in the mineral collection of the U. S. National Museum.

HEDYPHANE FROM FRANKLIN FURNACE, NEW JERSEY

Wm. F. Foshag, *U. S. National Museum*
and
R. B. Gage, *Trenton, N. J.*[1]

In a paper on the minerals of Langban, Sweden, C. Flink[2] lists hedyphane as one of the most typical minerals of that famous locality. It was with some interest, therefore, that the writers found among some minerals recently collected at Franklin Furnace, specimens of this same mineral. No doubt, this mineral has been frequently overlooked by the different collectors of Franklin Furnace minerals, for specimens of it have since then been identified in other collections.[3]

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[1] Published with the permission of the Secretary of the Smithsonian Institution.

[2] *Zeit. Krys.*, **58**, 357 (1923).

The hedyphane was found between the 500 and 600 ft. level on the east side of the ore deposit. Apparently, this locality is impregnated with arsenic minerals, for schallerite and chlorophoenecite came from the same place.

In general appearance, the Franklin Furnace hedyphane is similar to that found at Langban, but none of the fibrous variety has as yet been found at Franklin Furnace. The chief difference, however, is in the associated minerals. The Franklin Furnace material is found as seams in the willemite-franklinite ore, associated with calcite, rhodonite, willemite and sometimes native copper. In some of the specimens the hedyphane is the chief mineral, forming the matrix for the other species; in others calcite incloses the minerals. The willemite is of the glassy light green variety, often in crystals; the rhodonite occurs in light pink, wedge shaped crystals, while the copper is in distorted crystals. In the calcite the hedyphane may form irregular masses or occur as thick prismatic crystals bounded by the prism, base and unit pyramid.

In color the hedyphane ranges from pure white to light buff. It shows a rough conchoidal fracture and a decidedly greasy luster. It is very brittle and has a hardness of about three (3). In the closed tube, it decrepitates like barite, and forms an arsenic coating in the neck of the tube. Before the blowpipe the edge fuses at a fairly high temperature to a white, brown or black milky bead, depending upon the purity of the material. A slight coat of PbO and As_2O_3 can often be observed. Under the microscope it was found to be uniaxial with negative optical character and with indices as follows: $\omega = 2.026 \pm .01$, $\epsilon = 2.010 \pm .01$.

Material for analysis was selected from one of the specimens (U.S.N.M. 95193) and found on microscopic examination to be free of all extraneous material. Some of the grains, however, had a somewhat muddied appearance as if having been somewhat altered. The analytical results upon this sample is as follows:

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[3] Colonel W. A. Roebling, of Trenton, New Jersey, has a beautiful specimen of this material, containing well-developed crystals in a matrix of limestone. This specimen also contains native copper crystals, for which it was originally secured.

Analysis of hedyphane from Franklin Furnace, N.J.

Insol.		0.17
Cl		2.98
As_2O_5		29.94
PbO		52.77
MnO, FeO		0.28
CaO		14.98
MgO		0.10
ZnO		0.23
H_2O		0.08
		101.52
	$-O=Cl$	.67
		100.85

From the results given above the ratios of lime and lead are calculated as 267 and 236, respectively. Lime is molecularly in excess and hedyphane is predominantly a lime mineral. We therefore propose that hedyphane be accorded species rank and that the name be applied to those chloro-arsenates of the apatite group in which lime is molecularly the predominant base.

NOTES AND NEWS

The Mineralogical Society of America

Nominations of the Council for officers for the year 1926 are as follows:

President: Waldemar T. Schaller
Vice President: George Vaux, Jr.
Secretary: Frank R. Van Horn
Treasurer: Alexander H. Phillips
Editor: Walter F. Hunt
Councilor, 1925-29: W. A. Tarr

* * * *

A Committee of the Council was appointed at the last annual meeting to revise the Constitution and By-laws. This committee recommends that the following changes be made:

Constitution

Article III. Insertion of Section 2 to read as follows:

Section 2. The Council shall be empowered to elect from time to time as honorary officers or fellows of the Society persons of eminence in the field of mineralogy, or some closely allied science, who shall serve for life.

Arlicte V, to read as follows:

This constitution shall be amended when the proposed amendment is favored by four fifths of all the Fellows voting upon it. A copy of the proposed amendment shall be published in the journal of the Society at least three months before the annual meeting. Voting shall be by mail ballot.

By-Laws

Article II, *Section* 3, to read as follows:

An arrearage in payment of annual dues of four months shall deprive a Fellow or member of the privilege of taking part in the management of the Society and of receiving the publications of the Society. An arrearage continuing over two (2); years shall be construed as notification of withdrawal.

Article IV. Election of officers and Fellows shall read as follows:

Section I. Nominations for office shall be made by the Council. The list shall be published in the journal of the Society at least three months before the annual meeting. Any ten (10); Fellows or members may forward to the Secretary other nominations for any or all offices. All such nominations reaching the Secretary not later than November 1 shall be printed, together with the names of the nominators; as special ballots. The regular and special ballots shall then be mailed to the general membership. The results shall be announced at the annual meeting, and the officers thus elected shall enter upon duty at the adjournment of the meeting.

Section 2. The list of nominations for Fellowship in the Society shall be sent to the Fellows at the same time as the nominations for officers. Five opposing votes shall be considered as rendering a candidate ineligible for Fellowship.

* * * *

The next annual meeting will be held in the new Peabody Museum of Yale University, December 28-30, 1925. In order to appear on the advance program of the Geological Society of America, titles of papers for the Mineralogical Society should be in the hands of the Secretary by November 25.

FRANK R. VAN HORN, *Secretary*

The Mineralogical Society sustained a severe loss in the death of one of its most enthusiastic workers, Dr. Edward F. Holden. Although but twenty-four years of age at the time of his death he had made several notable contributions to the science of chemical mineralogy. He was particularly interested in the cause of color in minerals and his investigations on the color of rose quartz, amethyst and smoky quartz have appeared in recent issues. Dr. Holden was also one of the assistant editors of chemical abstracts and an associated editor of The American Mineralogist. A memorial sketch of his life will appear in a later number of the Journal.

Mr. Samuel G. Gordon of the Academy of Natural Sciences of Philadelphia, has returned from a six months trip to Bolivia and Chile. This trip represents the third of the Academy's mineralogical expeditions. Thirty-eight cases of specimens were secured including fine crystals of cassiterite, vivianite, vauxite, paravauxite, wavellite, teallite and jarosite.

An X-ray diffraction equipment, by which crystalline structure can be investigated, has been presented to Professor W. L. Bragg of the University of Manchester, England, by the General Electric Company of New York and the British Thomson-Houston Co., Ltd., of England.

Professor Louis Wade Currier, assistant professor in mineralogy at Syracuse University for the past four years, has accepted a similar position at the Missouri School of Mines.

Dr. John Jolly, professor of geology and mineralogy in the University of Dublin' has received the honorary degree of doctor of science from the University of Cambridge.

David B. Chisholm, teaching fellow in geology and mineralogy at Syracuse University for the past two, years has been appointed instructor in geology and mineralogy at Colgate University.